

PFA status

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PFA: the steps

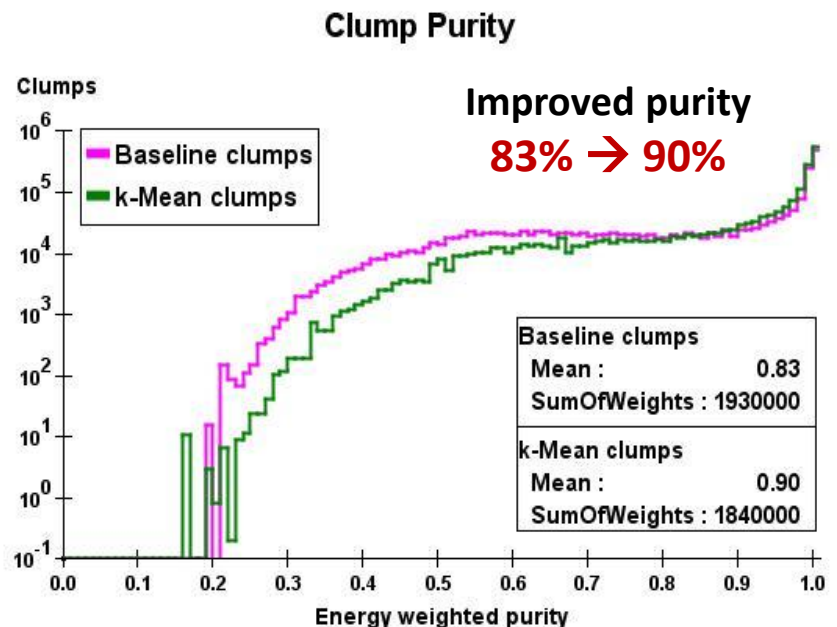
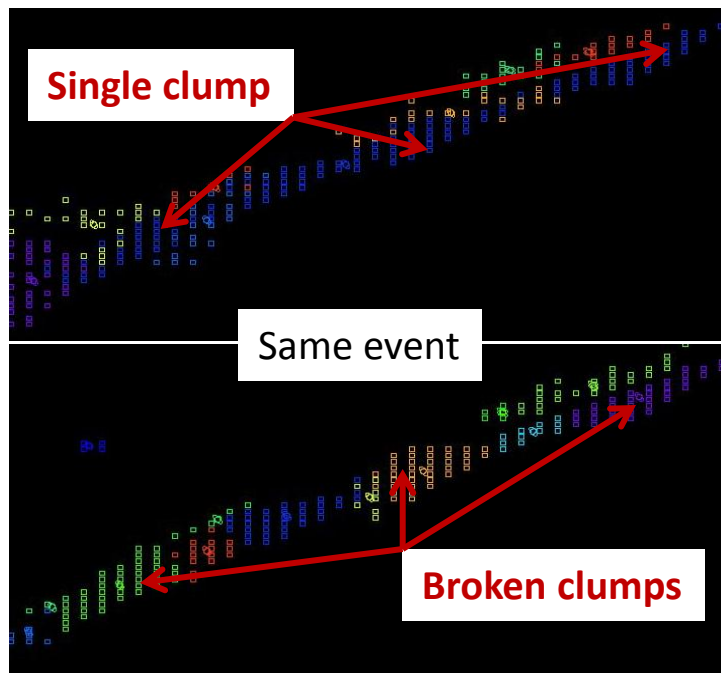
- Setup:
 - Photon finding
 - Electron finding
 - Muon finding
 - Pre-shower MIP finding
 - DTree clustering:
 - Uses only hits not used so far.
 - Sub-structure finding:
 - MIPs, Clumps, blocks and leftovers
 - Track-seed matching:
 - Uses initial MIP finding
 - Attempt to match unmatched tracks to sequentially to MIPs, Clumps and blocks, leftover hits then photons.
 - Photon veto:
 - A photon is considered as a hadron if it is within 3 degrees from a track.

PFA: the steps

- Shower building:
 - Link scoring:
 - Based on a likelihood
 - Categorized: Clumps/Mips, Ecal/Hcal
 - Cluster sharing:
 - Energy of the leftover hits is shared among linkable clusters.
 - Existing shower building:
 - Uses a cone algorithm along main shower axis.
 - Uses E/P check to prevent unphysical mistakes
 - Build showers for tracks one at a time starting from low momentum
 - Results are shown using this version.
 - Shower building under development:
 - First iteration: build high purity skeletons
 - Second iteration: build primary and secondary neutral showers
 - Third iteration: fix mistakes using the total event energy information
 - Particle making:
 - Construct 4-momentums for all kind of particles.

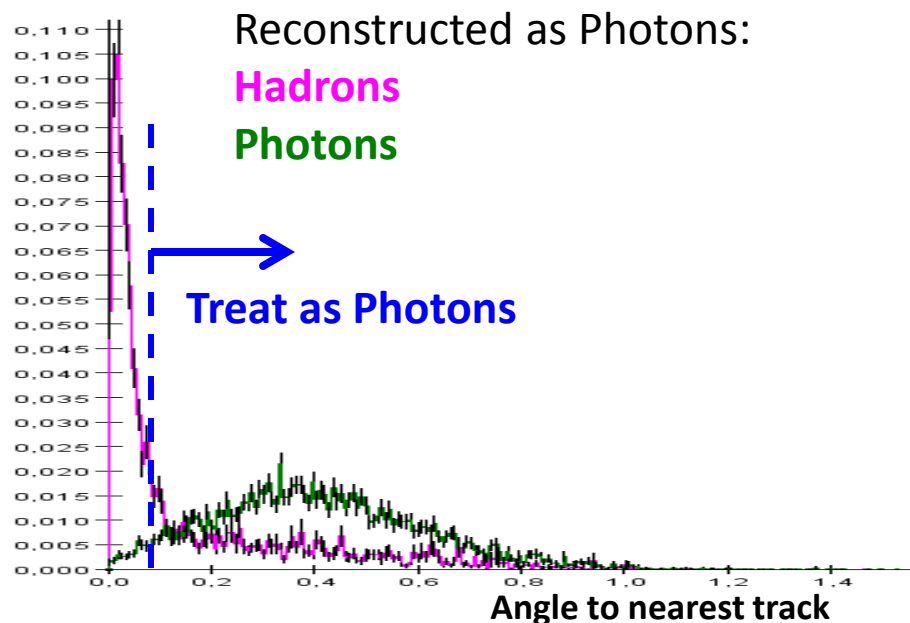
Sub-cluster finding

- Improved on Clump finding:
 - Implemented a new clump finding algorithm based on the k-mean clustering algorithm:
 - Clusters are seeded with local density maxima.
 - Hits are assigned to seeds based on proximity.



Photon veto

- Improved on photon purity:
 - Treat a reconstructed photon cluster as a hadronic clump if there is a track within 3 degrees of the photon.
 - We still have a 10% inefficiency and 10% contamination in the photon energy.



Purity:

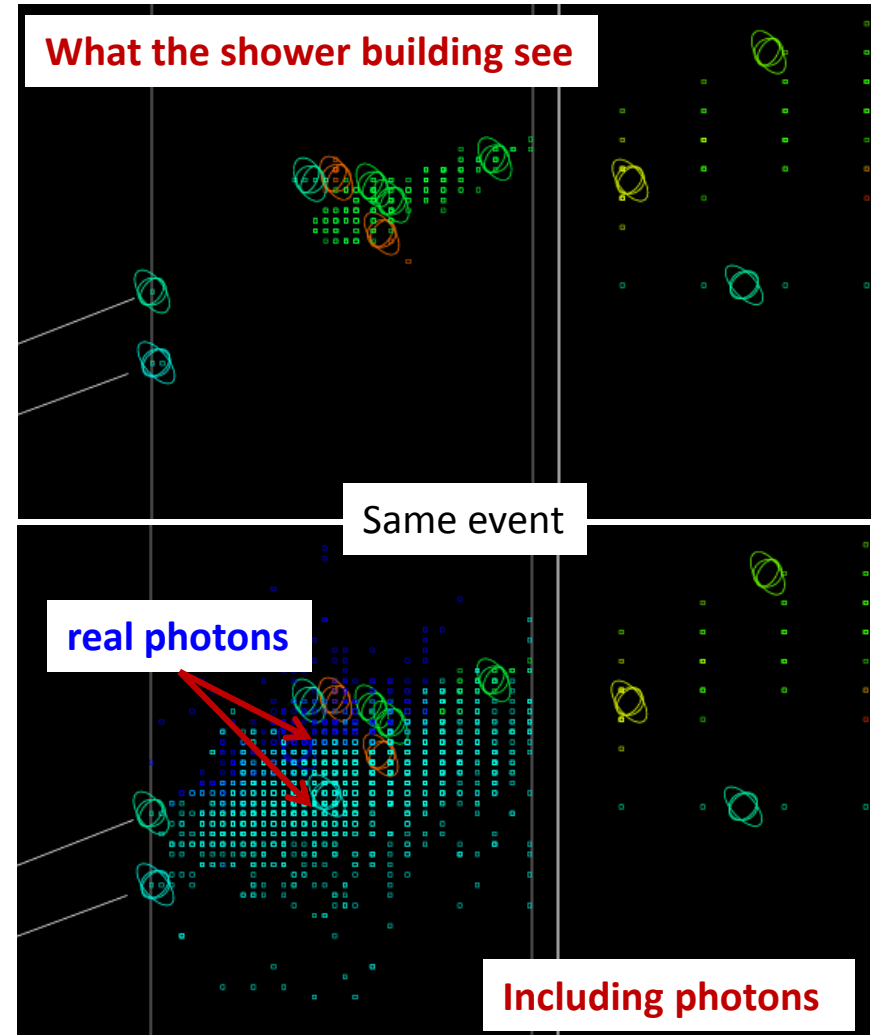
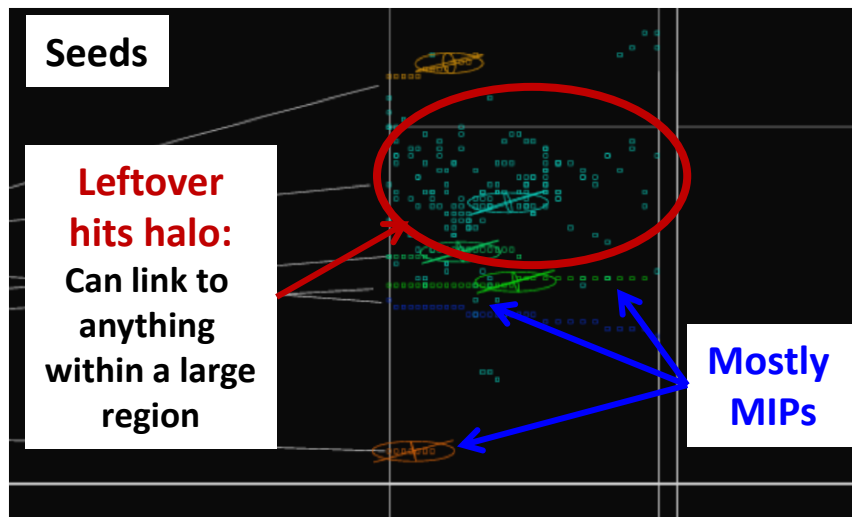
83% → 90%

Efficiency:

92% → 90%

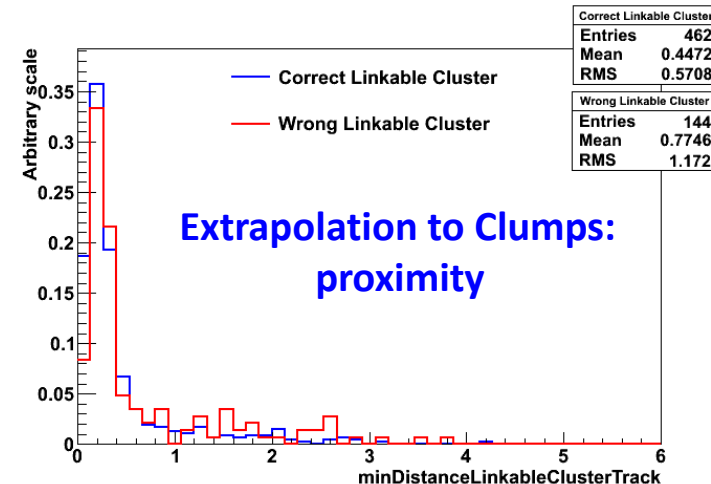
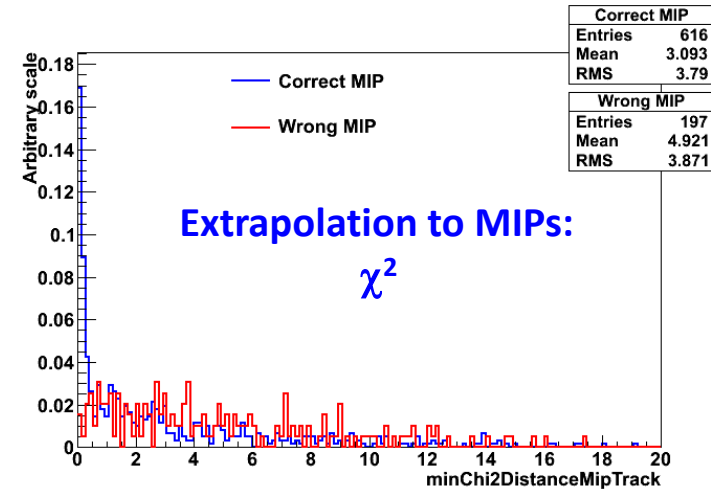
Track-seed matching

- Identified two categories of problems in the seeds assigned to tracks:
 - Short seeds masked by large photons.
 - Seeds that consist of leftover hits halos.



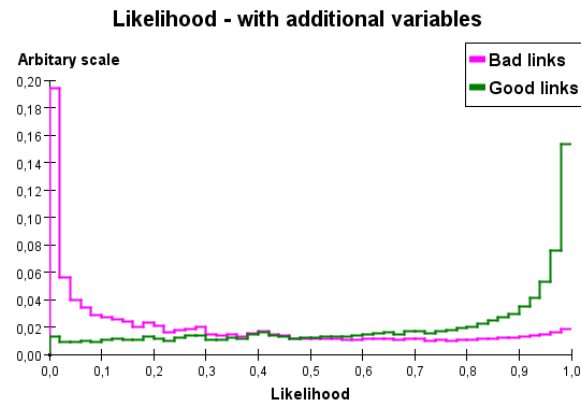
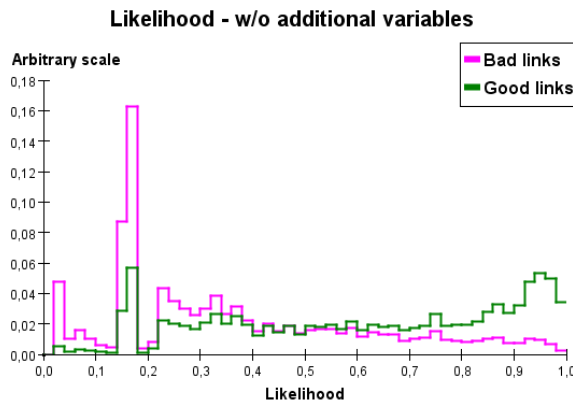
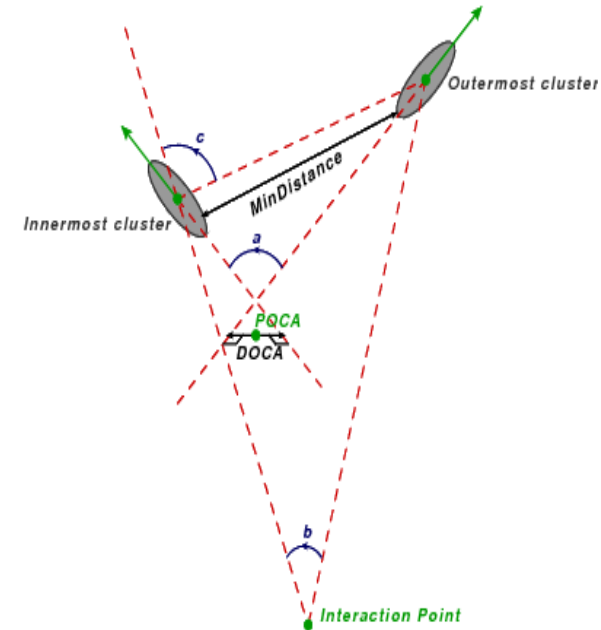
Fix by extrapolation

- Extrapolate the track into the calorimeter and try to match to a MIP:
 - Matching criteria is a χ^2 between the MIP and the track extrapolation taking the size of the cells as position uncertainty.
 - About 25% of the cases a match is found.
 - About 95% of the found MIPs actually belong to the track.
- Then try to match to a clump:
 - Extrapolate the track and pick-up the first clump it finds within a certain distance.
 - The distance is between the track extrapolation to a given layer and the closest hit of the clump on that layer.
 - Limit distance calculation to the first 3 layers of the clump.
 - About 75% of the found clumps actually belong to the track.
- Overall, about 80% of the found new seeds actually belong to the track.



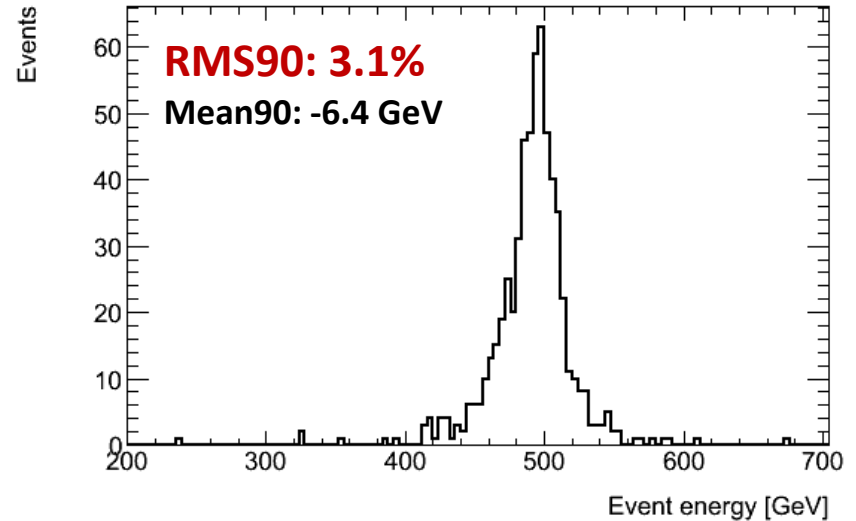
Link scoring

- Improved on likelihood for link scoring:
 - Added new geometrical variables
 - Use separate likelihood for different sub-detectors
 - Use the correct jet energy for likelihood training
 - Train the likelihood not to link indirect links:
 - If A can link to B and B can link to C, then A should not necessarily link to C.



PFA resolution: No cheating

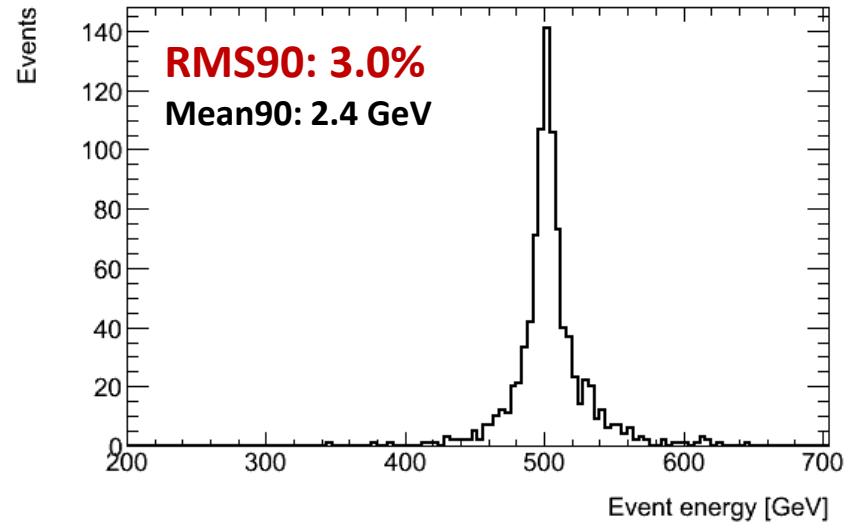
- Cheating with:
- Not cheating with:
 - Photon finding
 - Electron finding
 - Muon finding
 - Pre-shower MIP finding
 - DTree clustering
 - Sub-structure finding
 - Photon veto
 - Track-seed matching
 - Sharing of the leftovers
 - Link scoring
 - Charged shower building
 - Neutral shower building
 - Particle making
- Not affected by:



	Charged	Neutral	Photons	Purity
Reco as Charged	51.76	4.47	1.54	0.90
Reco as Neutral	6.60	8.11	1.97	0.49
Reco as Photons	3.11	0.86	21.58	0.84
Efficiency	0.84	0.60	0.86	

Perfect PFA: Cheat on shower building

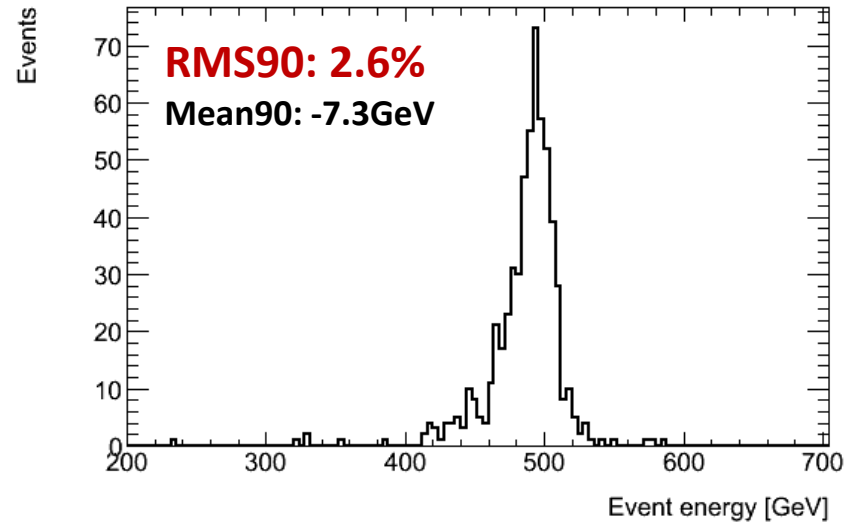
- Cheating with:
 - Charged shower building
 - Neutral shower building
- Not cheating with:
 - Photon finding
 - Electron finding
 - Muon finding
 - DTree clustering
 - Sub-structure finding
 - Photon veto
 - Sharing of the leftovers
 - Particle making
- Not affected by:
 - Pre-shower MIP finding
 - Track-seed matching
 - Link scoring



	Charged	Neutral	Photons	Purity
Reco as Charged	54.25	1.63	0.69	0.96
Reco as Neutral	3.14	9.81	2.15	0.65
Reco as Photons	3.04	0.94	24.34	0.86
Efficiency	0.90	0.79	0.90	

Perfect PFA: Cheat on photons

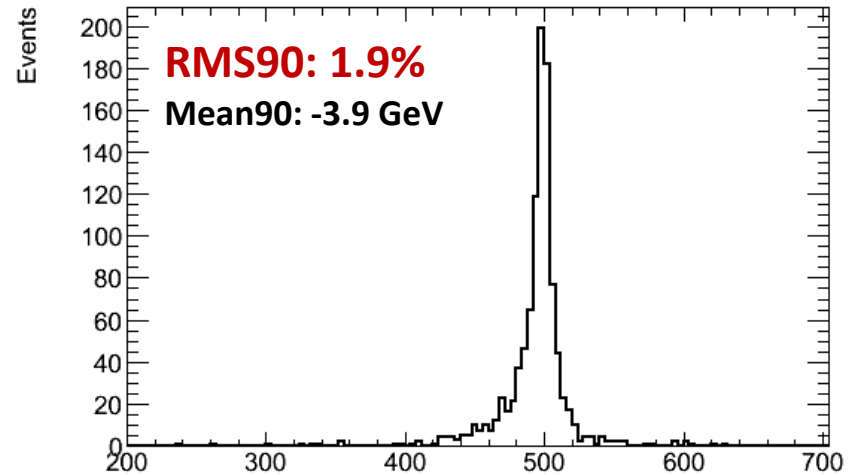
- Cheating with:
 - Photon finding
- Not cheating with:
 - Electron finding
 - Muon finding
 - Pre-shower MIP finding
 - DTree clustering
 - Sub-structure finding
 - Photon veto
 - Sharing of the leftovers
 - Particle making
 - Charged shower building
 - Neutral shower building
- Not affected by:
 - Track-seed matching
 - Link scoring



	Charged	Neutral	Photons	Purity
Reco as Charged	52.59	4.41	0.44	0.92
Reco as Neutral	6.71	8.83	0.11	0.56
Reco as Photons	1.76	0.00	25.16	0.93
Efficiency	0.86	0.67	0.98	

Perfect PFA: Cheat on photons and shower building

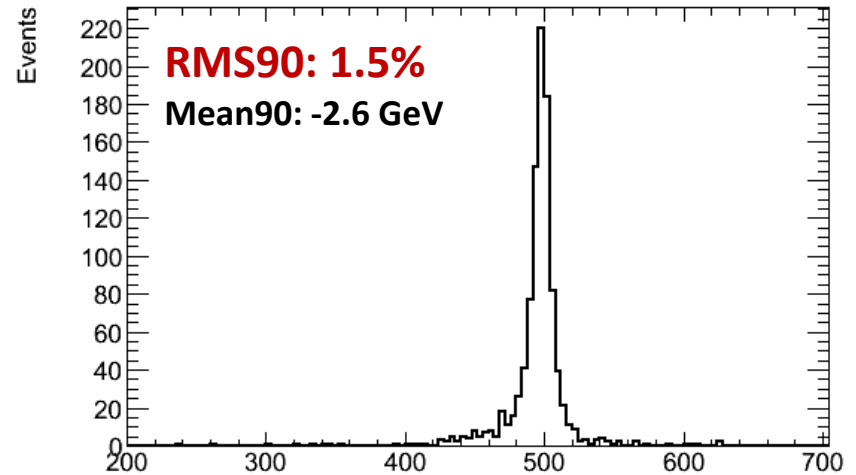
- Cheating with:
 - Photon finding
 - Charged shower building
 - Neutral shower building
- Not cheating with:
 - Electron finding
 - Muon finding
 - DTree clustering
 - Sub-structure finding
 - Photon veto
 - Sharing of the leftovers
 - Particle making
- Not affected by:
 - Pre-shower MIP finding
 - Track-seed matching
 - Link scoring



	Charged	Neutral	Photons	Purity
Reco as Charged	54.36	1.69	0.37	0.96
Reco as Neutral	5.19	11.01	0.08	0.68
Reco as Photons	1.78	0.00	25.53	0.93
Efficiency	0.89	0.87	0.98	

Perfect PFA: Cheat on photons, DTree and shower building

- Cheating with:
 - Photon finding
 - DTree clustering
 - Charged shower building
 - Neutral shower building
- Not cheating with:
 - Muon finding
 - Electron finding
 - Pre-shower MIP finding
 - Sub-structure finding
 - Photon veto
 - Sharing of the leftovers
 - Particle making
- Not affected by:
 - Pre-shower MIP finding
 - Track-seed matching
 - Link scoring



	Charged	Neutral	Photons	Purity
Reco as Charged	55.93	0.37	0.36	0.99
Reco as Neutral	4.20	12.49	0.08	0.75
Reco as Photons	1.74	0.00	24.84	0.93
Efficiency	0.90	0.97	0.98	

Conclusion

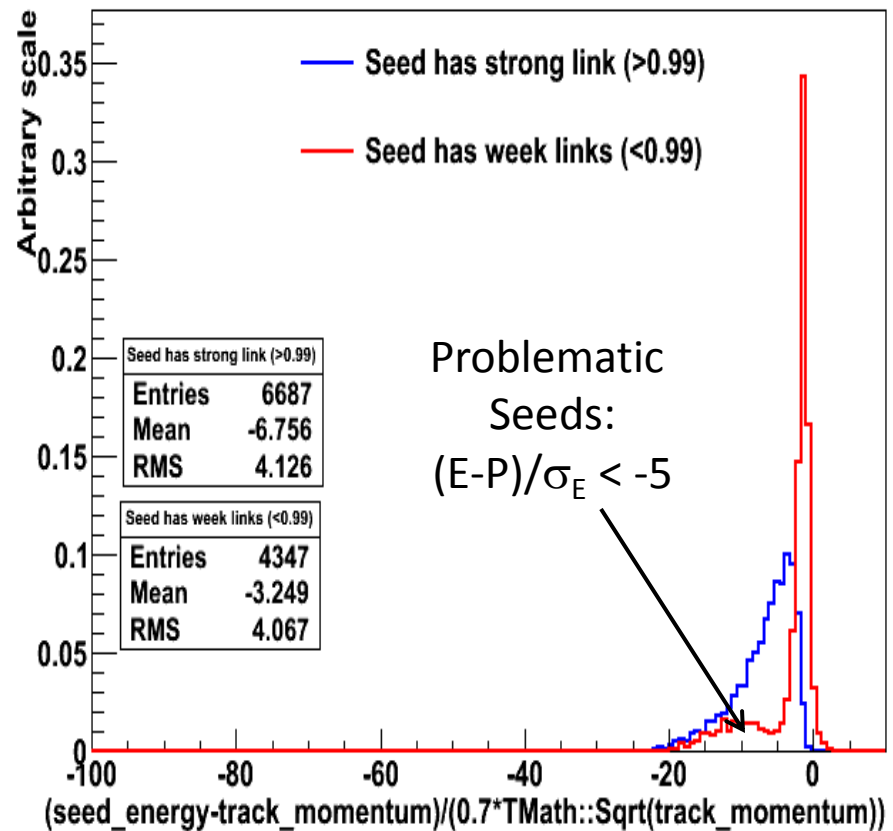
- Current status:
 - Limited by photon ID
 - 3.1% \rightarrow 2.6% with perfect photons
 - 3.1% \rightarrow 3.0% with perfect shower building
- Shower building is being re-written to scale better at higher energies:
 - Large progress has already been made in this area.
 - Charged shower trunks (first iteration) ... done
 - Neutral (primary and secondary) showers (second iteration) ... done
 - Need to implement a third iteration using a global event energy constraint ... in progress
 - Will not be ready for Spain workshop.

Back-up

Track-seed matching

- Identifying problematic seeds:

- Some seeds don't have a chance to propagate into a shower because they don't link to anything with sufficiently high score:
 - Most of these seeds correspond to low momentum tracks and the seed itself satisfies the E/P balance
 - Some don't satisfy the E/P balance: they should link to something but they don't!

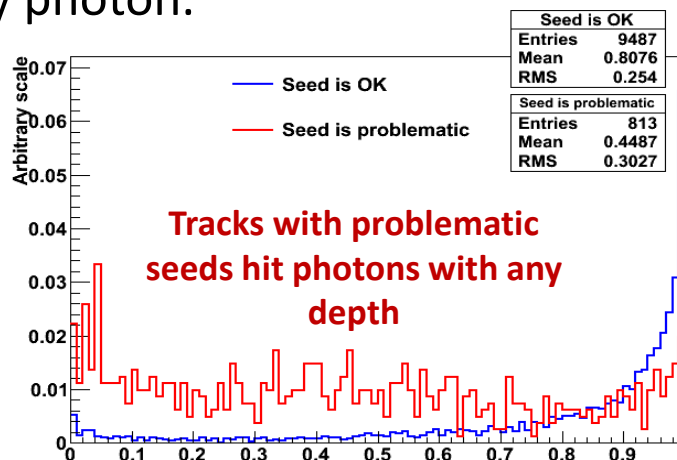
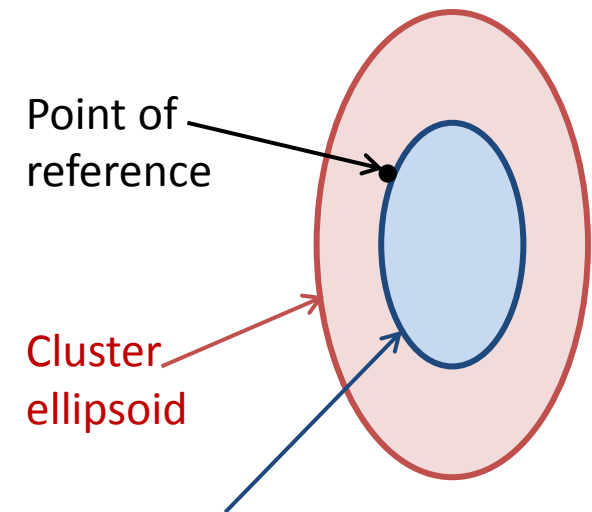


Track/photon proximity

- Shallowness of a point in a photon:

$$\text{shallowness} = \frac{\text{Energy IN}}{\text{Energy IN} + \text{Energy OUT}}$$

- Shallowness of a track in a photon:
 - Extrapolate the tracks at each layer of the photon, and compute the shallowness of the intercept point in the photon.
 - Compute the minimal shallowness over all photon layers.
- Compute the minimal shallowness of the track to any photon.



Properties of the problematic seeds

- 8% of matched tracks have problematic seeds:
 - On average 1/3 of events have one or more problematic seed.
- They have high momentum:
 - 60 GeV on average instead of 20 GeV for all tracks.
- They have low number of hits:
 - 90% of them have less than 4 hits.
- There is a big photon nearby

